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FOOD AND COCAINE SELF-ADMINISTRATION BY BABOONS: EFFECTS OF ALTERNATIVES

RICHARD W. FOLTIN

NEW YORK STATE PSYCHIATRIC INSTITUTE AND COLUMBIA UNIVERSITY

The effects of the availability of an alternative reinforcer on responding maintained by food pellets or drug solutions were examined in 8 adult male baboons (*Papio hamadrayas anubis*). During daily 23-hr experimental sessions, baboons had access to both food pellets and fluid under a two-choice procedure, in which the response requirement, under a fixed-ratio schedule, differed for the two commodities. There were no restrictions on access to water, which was continuously available from a spout at the rear of each cage. In Experiment 1, the fixed-ratio requirement, or *cost*, for fluid delivery remained constant while the fixed-ratio requirement for pellets was changed every 2 or 3 days when (a) no fluid, (b) a dilute dextrose vehicle, (c) 0.008 mg/kg per delivery cocaine, (d) 0.016 mg/kg per delivery cocaine, or (e) 0.032 mg/kg per delivery cocaine was available concurrently. In Experiment 1, progressively increasing the response requirement for pellets decreased pellet intake, but for 4 baboons pellet intake at maximum pellet cost was lower when cocaine, compared to the vehicle, was available. Increasing the response requirement for pellets had variable effects on vehicle intake. However, increasing the response requirement for pellets increased intake of at least one dose of cocaine to a greater extent than vehicle in all 8 baboons. Thus, cocaine could be considered a more effective economic substitute than vehicle for pellets. Experiment 2 systematically varied the order in which the response requirements for a pellet delivery were presented and added a control condition in which cocaine doses, yoked to the amount self-administered, were given three times during the session by the experimenter. Again, pellet intake at maximal pellet cost was lower when cocaine, compared to the vehicle, was available. In contrast, experimenter-given cocaine doses did not alter responding maintained by pellets. Thus, the effects of self-administered cocaine on responding maintained by food pellets differed from the effects of experimenter-given cocaine on responding maintained by food pellets.

Key words: cocaine, food intake, ratio schedules, self-administration, behavioral economics, lever pull, baboon

The vast majority of studies examining drug or food self-administration have had only one commodity available at a time. By contrast, individuals are continuously exposed to a large number of commodities in the natural ecology, such that the acquisition and consumption of any commodity is influenced by the available alternatives. Proponents of behavioral economics have argued that the interactions among commodities can best be understood within a context of examining the effects of changing the cost of a commodity on intake of that commodity and of the available alternatives. Thus, as in behavioral pharmacology, in which an understanding of drug action is based upon the analysis of the effects of multiple drug doses (e.g., a dose–response function; Seiden & Dykstra, 1977), the understanding of interactions among commodities must be based upon the analysis of commodity intake across a range of costs (e.g., a demand function; Hursh & Bauman, 1987). Increasing the cost of a commodity will increase responding maintained by that commodity until a cost is reached that maximizes responding. Increasing the cost above the one that produces maximal responding will cause responding to decrease below maximal levels.

Commodities can be characterized as independent of each other, complementary to each other, or as substitutes for each other, depending upon the effects on intake of a second commodity, when cost for the primary commodity is increased, assuming the laboratory situation does not constrain responding for the second commodity (e.g., not enough time during the session for responding for both commodities; Green & Freed,

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Reprints may be obtained from the author at New York State Psychiatric Institute, 1051 Riverside Drive, Unit 120, New York, New York 10032 (E-mail: rwf2@columbia.edu).

1993; Hursh & Bauman, 1987). Consumption of the second commodity may remain stable as consumption of the primary commodity decreases (i.e., the commodities are independent, such as bow ties and potatoes); consumption of the second commodity may decrease as consumption of the primary commodity decreases (i.e., the commodities are complements, such as computer disks and computer software); or consumption of the second commodity may increase as consumption of the primary commodity decreases (i.e., the commodities are substitutes, such as sirloin steak and filet mignon).

Although interactions among commodities often can be predicted by physical characteristics (e.g., different brands of socks, pens and pencils), even in these cases it may be difficult to predict how changing the cost for one commodity will affect intake of the other. Clearly, most studies involving drug self-administration and an alternative reinforcer fall within the category of difficult-to-predict interactions. Studies have shown that the interaction between drug and food self-administration is complex, such that the interactive effects of a nondrug reinforcer on drug self-administration are influenced by the cost of each commodity, income, and the stability of drug self-administration (Carroll, Lac, & Nygaard, 1989; Carroll & Rodefer, 1993). Bickel and DeGrandpre (1995) argued that increasing the availability of "competing nondrug reinforcers" may be effective in reducing human drug abuse. The economic construct of substitution may provide a useful framework for describing the complex interactions among reinforcers (Bickel, DeGrandpre, & Higgins, 1995; Carroll, 1996).

Two studies from our laboratory have examined the effects of increasing the response cost for food pellets on intake of orally self-administered drugs by baboons (Foltin, 1997, 1998). Increasing the cost of pellets had effects on the intake of *d*-amphetamine that varied across baboons. Although amphetamine intake increased at one dose for most baboons, the increase was not statisically significant for the group and, when expressed as change from baseline, did not differ from the increase in vehicle intake for the group (Foltin, 1997). In another study, increasing the cost of food pellets increased oral consumption of a 4%, but not a 2% or 8%, ethanol solution (Foltin, 1998). Thus, although self-administered drug did function as an economic substitute for food, the substitution was variable across animals and was not necessarily dose dependent.

The purpose of Experiment 1 was to examine the extent to which orally self-administered cocaine (Falk, Fang, & Lau, 1991; Falk & Lau, 1993; Meisch, Bell, & Lemaire, 1993; Meisch, George, & Lemaire, 1990) would serve as a substitute, as defined in behavioral economics, for self-administered food pellets in baboons. The reinforcing efficacy of oral cocaine is controversial (e.g., Falk, Siris, & Lau, 1996; Macenski & Meisch, 1995; Meisch et al., 1993; Tang & Falk, 1987). In the present study, responding maintained by oral cocaine was recorded when the operant requirement to obtain concurrently available food pellets was increased for baboons who were required to earn all their daily food during sessions (i.e., no supplemental food was provided).

In a previous study (Foltin, 1997), when total daily pellet intake was restricted to 70% of baseline, increasing the response requirement for pellets decreased pellet intake at a faster rate when a high dose of amphetamine was available compared to when vehicle was available. This more rapid decrease in pellet intake with increasing pellet cost when amphetamine was available was not observed when there were no restrictions on maximal pellet intake. Similarly, the rate of decrease in pellet intake with increasing pellet cost was unaffected by the availability of ethanol solutions when there were no restrictions on maximal pellet intake (Foltin, 1998). Thus, the availability of a drug to self-administer can alter the amount of work a laboratory animal will perform in order to earn food as the cost for food is increased.

EXPERIMENT 1

Method

Subjects. Eight adult male baboons (*Papio hamadrayas anubis*; Southwest Foundation for Medical Research), initially weighing 23.2 to 49.1 kg, were housed in standard primate cages (0.94 m by 1.21 m by 1.52 m high). The baboons had 4 to 6 years of experience responding under fixed-ratio (FR) schedules of pellet and fluid delivery. The room was illuminated with fluorescent lighting from 6:00 a.m. to 6:00 p.m. daily. In addition to pellets and fluid earned during experimental sessions, two chewable vitamins (Kiddy Chews, Schein Pharmaceutical, Inc.), two pieces of fresh fruit (80 to 100 kcal each), and a dog biscuit (150 kcal, Old Mother Hubbard, Inc.) were given daily. Water was available ad libitum from a spout located at the back of each cage. Because it was necessary to sedate the baboons to determine their body weights, weight was determined every 3 months. Over the 9-month experiment, weights decreased between 0.0 and 2.3 kg in the 6 baboons that had restricted access to pellets and increased by 0.9 and 3.0 kg in the 2 baboons that had nonrestricted access to pellets.

Apparatus. A response panel holding, from bottom to top, a pellet hopper, two Lindsley levers spaced 0.30 m apart (Gerbrands), four stimulus lights (two above each lever), a fluid spout, and a pellet dispenser (BRS-LVE model PDC-005) was attached to the front of each cage. The dispenser contained Noyes Formula L® banana-flavored 1-g food pellets (3.7 kcal per gram: 21.0% protein, 4.7% fat, 62.0% carbohydrate, 5.3% ash, 3.1% moisture, and 3.0% fiber). Resting on a shelf atop each cage was a 4-L bottle for fluid solutions and a peristaltic pump (7543-06 with pump head 7016 resulting in a flow rate of 10 ml per minute; Cole Parmer Instrument Co.). The fluid solution was a dilute dextrose solution (D-(+)- glucose; Sigma Chemical Corp.). All schedule contingencies were programmed using Pascal on Apple® IIgs computers located, along with the interface, in an adjacent room.

Procedure. Responding was maintained under a choice procedure in a which a food pellet was available for completing a fixed number of responses on the right lever (i.e., FR schedule of reinforcement), and a fluid was available under an FR schedule for responding on the left lever. At the beginning of the session, the red stimulus light above each lever was illuminated. The first response on either of the two levers defined a choice: The red lights were extinguished, a green light above that lever was illuminated, and the limited hold began. The duration of the limited hold was the FR value times 10 s. Responses on the alternate lever were counted but had no programmed consequences. Completion of the FR response requirement within the limited hold produced a reinforcer, turned off the green light, and began a 30-s timeout. During the timeout, responding was recorded but had no programmed consequences. If the response requirement was not completed within the limited hold, the green light was turned off, the response requirement was reset, and the timeout began. At the end of the timeout, the red lights over both levers were illuminated and another choice was available. The schedule was in effect 23 hr per day, 7 days per week, from 10:00 a.m. to 9:00 a.m. the following morning. Restrictions on pellet and fluid intake are described below. The remaining hour of the day was used for cage and animal maintenance. During the timeout and maintenance periods, no stimulus lights were illuminated.

Initially, the FR requirement for both commodities was two responses, and resulted in the delivery of one pellet or 5 ml of fluid over 30 s. The response requirement for pellets was increased on Mondays, Wednesdays, and Fridays, while fluid was always available under an FR 2 schedule. Each pellet cost was thus in effect for 2 or 3 days. It was unusual for a baboon not to eat a pellet or drink the fluid when delivered. Drop pans were inspected daily. Any pellets in the pan were counted and any stains from fruit drink were noted.

Large individual differences in pellet intake occur as a function of pellet cost (e.g., under an FR 128 some baboons will consume 200 g, whereas others will consume 50 g). In order to provide a range of functionally equivalent pellet intakes for these 8 baboons, the range of FR values differed across subsets of baboons: Baboons 1, 3, 4, 5, and 6 were tested at FR 2, 16, 32, 64, 128, and 160; Baboons 4 and 8 were tested at FR 2, 8, 16, 32, 48, and 64; and Baboon 7 was tested at FR 2, 8, 16, 32, and 48. These FR values were individually chosen based on previous studies with these baboons in which the FR requirement for food pellets was altered.

For 6 of the 8 baboons, total daily pellet intake was restricted to 60% to 70% of nonrestricted intake. Prior to the study, responding was maintained under an FR 2 schedule of pellet delivery without fluid (except water) available for 2 weeks. This provided the baseline intake that was used to determine pellet

Table 1

Order in which cocaine solutions (mg/kg/delivery), its vehicle (a dextrose solution), or no fluid was available concurrently with food pellets for each baboon in Experiment 1.

Baboon	Condition 1	2	3	4	5
1	No fluid	0.008	0.016	Vehicle	
2	0.008	0.016	0.032	Vehicle	No fluid
3	Vehicle	No fluid	0.016	0.008	0.032
4	No fluid	Vehicle	0.016	0.032	0.008
5	No fluid	Vehicle	0.032	0.016	0.008
6	0.016	0.008	0.032	Vehicle	No fluid
7	No fluid	Vehicle	0.016	0.008	0.032
8	No fluid	Vehicle	0.008	0.016	0.032

intake under nonrestricted access conditions. The extent of the pellet restriction was based on the starting weights of the baboons. For Baboons 3, 4, 5, and 7 (23.2 to 29.9 kg), the maximum number of pellets that could be earned each day was set to 80% of baseline for 1 month and then reduced to 70% for 1 month prior to the study. For the 2 heaviest baboons (Baboon 1, 49.1 kg; Baboon 8, 40.3 kg), the maximum number of pellets that could be earned each day was set to 80% of baseline for 1 month, reduced to 70% for 1 month, and finally reduced to 60% for 1 month prior to the study. For Baboons 2 and 6 (24.4 and 31.0 kg), there was no restriction on pellet intake other than that due to increasing cost. Once a baboon had earned all of his pellets during a session, the red stimulus light above the food lever was no longer illuminated, responding on the pellet lever had no programmed consequences, and only the fluid was available for the remainder of that session.

The response requirement for pellets was increased when baboons had access only to pellets (no alternative condition) and when they had access to pellets and each of four fluids: (a) dilute dextrose vehicle solution (0.625 or 1.25 kcal per delivery), (b) 0.008 mg/kg per delivery cocaine, (c) 0.016 mg/kg per delivery cocaine, and (d) 0.032 mg/kg per delivery cocaine. As shown in Table 1, the order of testing fluid conditions systematically varied among baboons. When baboons first were given access to the dextrose vehicle and whenever the fluid commodity was changed, responding was maintained under an FR 2 schedule of pellet delivery and an FR 2 schedule of fluid delivery for 7 to 10 days to allow fluid intake to stabilize (no upward or downward trends in intake).

Data analysis. Total daily pellet and fluid intake, total length of time spent responding on the food and fluid levers, latencies to the first food pellet and to the first fluid delivery, and the proportion of the total daily number of food pellets delivered prior to the first fluid delivery were analyzed using repeated measures analyses of variance with two within-subject factors for the 6 baboons that were maintained under restricted pellet-access conditions. The first factor was the categorical variable experimental condition (no alternative, in analyses of food intake only; dextrose; low, medium, and high cocaine doses), and the second factor was pellet cost, which was treated as an ordinal, rather than a numerical, variable. For each dependent measure, a single planned comparison was also accomplished by comparing results obtained under each of the three cocaine conditions to the dextrose condition under the maximum pellet cost. Results were considered statistically significant at $p < .05$.

Results

Figures 1 and 2 present the total number of daily pellets and fluid deliveries as a function of pellet cost for each of the 8 baboons. The minimum number of reinforcers obtained under each FR condition almost always occurred on the 1st day of that condition, except under FR 2, when maximal responding usually occurred on the 1st day. Because FR values were tested in increasing order, FR 2 conditions always occurred after the largest FR tested for each baboon, when pellet intake had been the lowest. Because of this order effect, data presented in the figures are for the 2nd day of 2-day conditions and the 3rd day of 3-day conditions.

When no alternative was available, increasing the cost of pellets decreased pellet intake for 7 of 8 baboons (all but Baboon 3). Increasing the cost of pellets decreased pellet intake more when dextrose was available than when no alternative was available for only 3 baboons (Baboons 4, 5, and 8) with restricted access to pellets but for both baboons with nonrestricted access to pellets. Thus, increasing the FR value decreased pellet intake to a

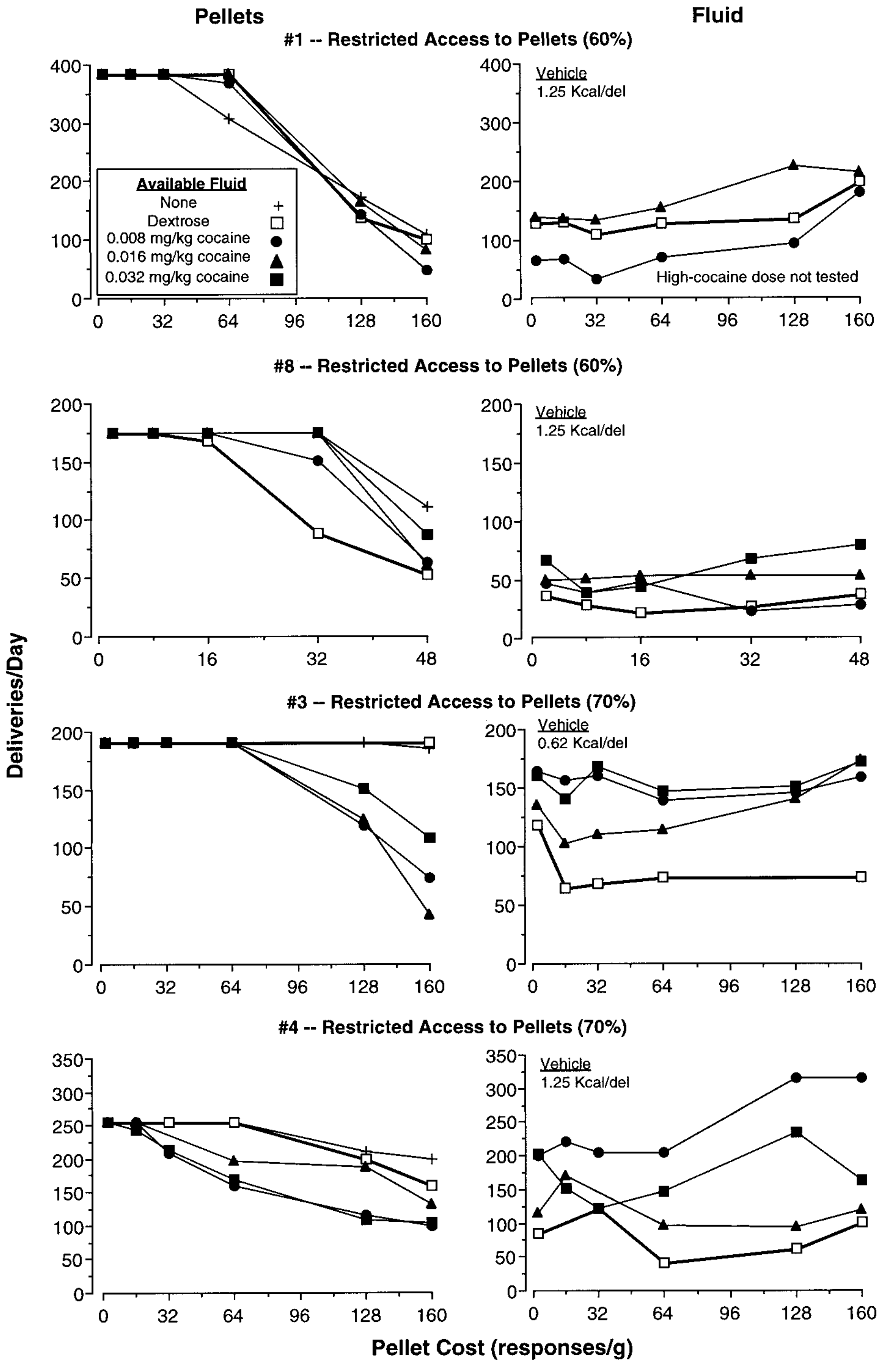

Fig. 1. Total daily number of pellet (left panels) and fluid (right panels) deliveries on the last of 2 or 3 days at each pellet cost as a function of pellet cost and available fluid for each of 4 baboons (1, 8, 3, and 4) that had restricted access to pellets. The number of pellet deliveries was limited to 60% or 70% of the total daily number of deliveries each baboon had received when pellets were available under an FR 2 schedule.

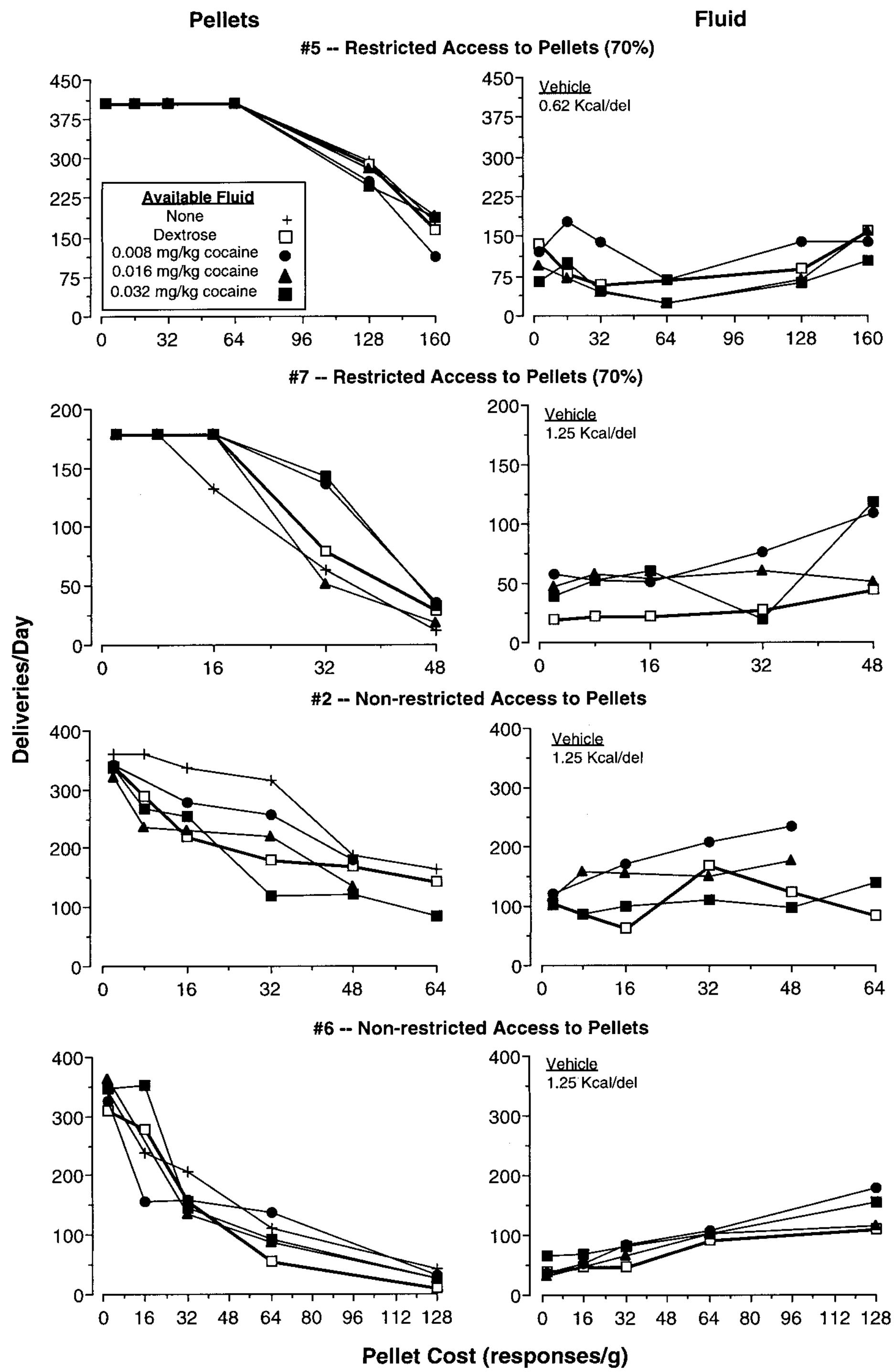

Fig. 2. Total daily number of pellet (left panels) and fluid (right panels) deliveries on the last of 2 or 3 days at each pellet cost as a function of pellet cost and available fluid for Baboons 5 and 7, which had restricted access to pellets, and Baboons 2 and 6, which had nonrestricted access to pellets. For the former baboons, the number of pellet deliveries was limited to 70% of the total daily number of deliveries each baboon had received when pellets were available under an FR 2 schedule.

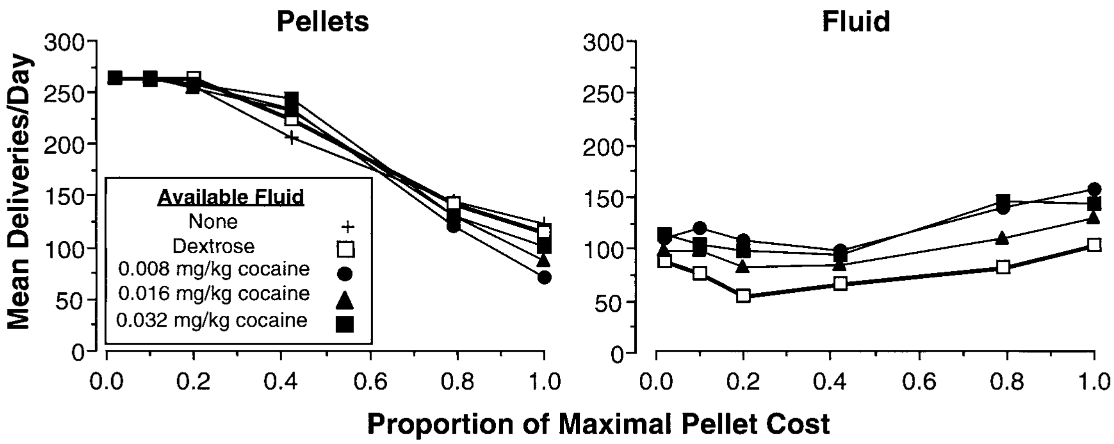

Fig. 3. Mean total daily number of pellet (left panels) and fluid (right panels) deliveries as a function of pellet cost and available fluid for the 6 baboons that had restricted access to pellets. Individual data are shown in Figures 1 and 2.

greater extent when a dextrose solution was also available compared to when no caloric alternative was available for 5 of 8 baboons.

When at least one of the three concentrations of cocaine was available, increasing the cost of pellets decreased pellet intake to a greater extent, compared to when the dextrose vehicle was available for Baboons 1, 3, 4, and 5 with restricted access to pellets and Baboon 2 with nonrestricted access to pellets. This effect of cocaine was most dramatic in Baboons 3 and 4, for which pellet intake at each FR value was lower when all three doses of cocaine were available compared to when vehicle was available. The decrease in pellet intake with increasing FR value when cocaine was available was not dose dependent for 5 baboons.

The results also provide data on changes in fluid intake in response to increased pellet cost. Although increasing the cost of pellets increased vehicle intake for 6 of 8 baboons, this increase was small for Baboons 4 and 5 and was not reliably related to pellet cost for Baboon 2. By contrast, intake of at least one dose of cocaine increased to a greater extent than vehicle intake when the cost for pellets was increased for all 8 baboons. As described above for the effects of cocaine availability on pellet intake, the increases in cocaine intake when the cost of pellets was increased varied among baboons and were not dose dependent.

Figure 3 compares the mean total daily pellet and fluid intake as a function of pellet cost for the 6 baboons tested with restricted access to pellets. The statistical analyses of data obtained from these 6 baboons confirmed that pellet intake was significantly related to the caloric alternative, $F(20, 100) = 1.82$, $p < .028$. As shown in the left panel of Figure 3, pellet intake decreased to 125 when only pellets were available, to 120 when dextrose was available, to 65 when the low cocaine dose was available, to 88 when the medium cocaine dose was available, and to 100 when the high cocaine dose was available. At maximum pellet cost, total daily pellet intake was significantly lower under all three cocaine conditions than under the vehicle condition, $F(1, 100) = 18.80$, $p < .0001$. Because pellet intake appeared to be greater when cocaine was available under the 0.40 maximum cost, an additional post hoc comparison was calculated comparing all three cocaine conditions to vehicle at that cost: Total daily pellet intake was significantly greater under all three cocaine conditions than under the vehicle condition at that cost, $F(1, 100) = 9.78$, $p < .002$.

Increasing the pellet cost also significantly increased the number of fluid deliveries, $F(5, 25) = 6.11$, $p < .0008$ (right panel of Figure 3). When expressed as percentage change from the number of fluid deliveries when pellets were available at minimum cost, dextrose deliveries increased by 18%, low-dose cocaine deliveries increased by 42%, medium-dose deliveries increased by 33%, and high-dose deliveries increased by 27%. When pellet cost was maximal, total daily fluid intake was significantly greater under all three cocaine conditions than under the vehicle condition, $F(1, 100) = 13.98$, $p < .0004$.

The top panel of Figure 4 compares the total duration of responding on the pellet lever (i.e., the accumulated time from the first response of the ratio until the completion of the ratio) as a function of maximum pellet cost and fluid condition in the 6 baboons tested with restricted access to pellets (see the Appendix for individual data). At minimum pellet cost (FR 2) baboons responded about 2 min per day on the pellet lever. Duration of responding on the pellet lever varied significantly as a function of pellet cost, $F(5, 25) = 7.20$, $p < .0003$. Baboons responded on the pellet lever at most about 2.5 hr per day. Baboons spent less time responding on the pellet lever when either vehicle or cocaine was available.

At the minimum pellet cost (FR 2) baboons responded about 90 s per day on the fluid lever (data not shown). Duration of responding on the fluid lever varied significantly as a function of pellet cost, $F(5, 25) = 3.85$, $p < .01$. Baboons responded on the fluid lever at most about 2 min per day. At maximum pellet cost, total duration of responding on the fluid lever was significantly greater under all three cocaine conditions than under the vehicle condition, $F(1, 100) = 6.54$, $p < .01$. Thus, increasing the cost of pellet delivery increased the length of time baboons spent responding on both levers, but the daily total length of time spent responding on both food and fluid levers was rarely greater than 3 hr. Given that baboons had 23 hr each day to earn their daily food pellet ration, it is clear that session duration did not limit the ability of baboons to maintain pellet intake in the face of increasing pellet costs.

The middle panel of Figure 4 compares the latency to the first fluid delivery as a function of maximum pellet cost and fluid condition in the 6 baboons tested with restricted access to pellets (see the Appendix for individual data). At the minimum pellet cost (FR 2) the first fluid delivery was earned about 3 hr after the start of the session. Latency to the first fluid delivery varied significantly as a function of pellet cost, $F(5, 25) = 8.78$, $p < .0001$. Latency decreased to less than 1 hr when pellets were available at maximum cost. The latency to the first fluid delivery did not vary systematically as a function of fluid condition.

At the minimum pellet cost (FR 2), the first pellet delivery was earned about 30 s after the start of the session (data not shown). Latency to the first pellet delivery varied significantly as a function of pellet cost, $F(5, 25) = 7.63$, $p < .0002$. Latency increased to about 2 min when pellets were available at maximum cost. Changes in the latency to the first pellet delivery did not vary as a function of fluid condition.

The bottom panel of Figure 4 compares the proportion of total daily pellet deliveries received prior to the first fluid delivery as a function of maximum pellet cost and fluid condition in the 6 baboons tested with restricted access to pellets (see the Appendix for individual data). At the minimum pellet cost (FR 2) baboons earned about 90% of their total daily pellets prior to responding for and receiving their first fluid delivery of the session. Proportion of daily pellet deliveries that occurred prior to the first fluid delivery varied significantly as a function of pellet cost, $F(5, 25) = 32.27$, $p < .0001$. The proportion decreased to about 15% when pellets were available at maximum cost. Changes in the proportion of daily pellet deliveries that occurred prior to the first fluid delivery did not vary as a function of fluid condition. When access to pellets was restricted, baboons consumed nearly all of their daily pellet ration prior to responding for fluid (data not shown). By contrast, Baboon 2, with nonrestricted access to pellets, earned between 1% and 4% of his daily pellet deliveries prior to responding for fluid, and Baboon 6, with nonrestricted access to pellets, earned between 1% and 21% of his daily pellet deliveries prior to responding for fluid. The proportion of daily pellet deliveries that occurred prior to the first fluid delivery did not change as a function of increasing pellet cost or fluid condition for those baboons. Although the procedure allowed concurrent access to pellets and fluid in baboons with restricted access to pellets, their pattern of responding when pellets were available at minimum cost was one of successive, rather than concurrent, consumption of the two commodities. Finally, throughout the study baboons continued to drink the freely avail-

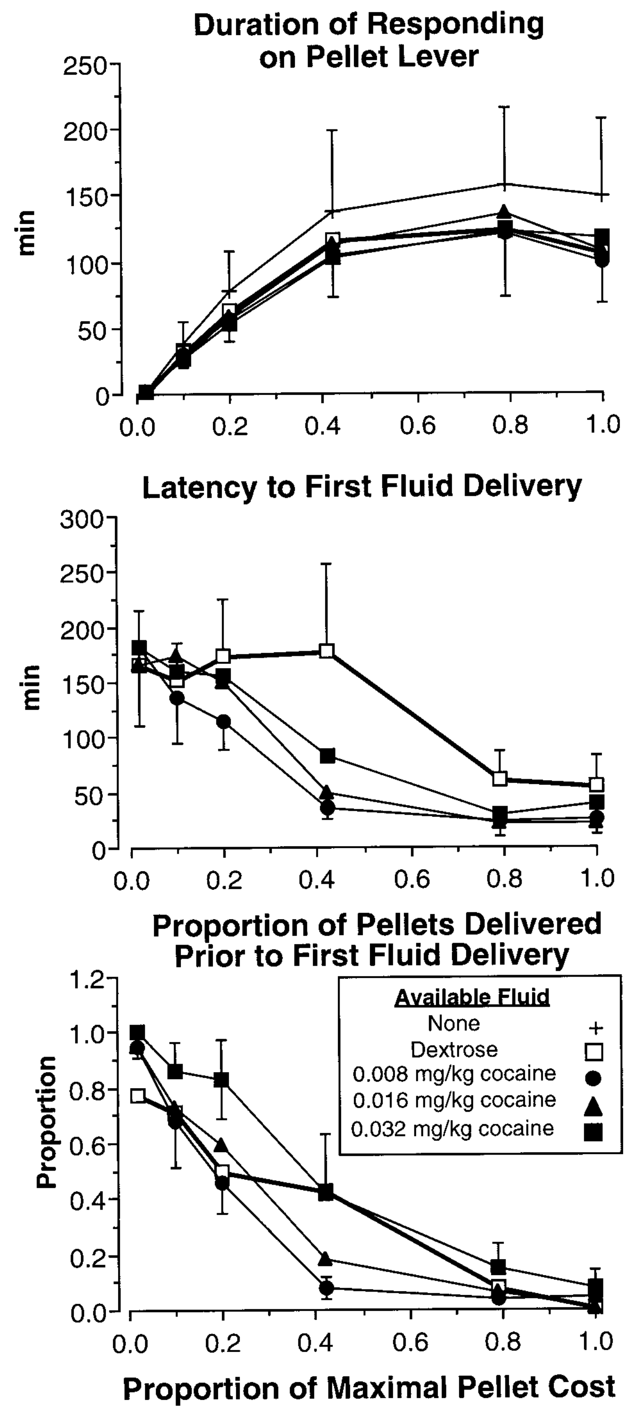

Fig. 4. Mean duration of responding on the pellet lever (top panel), mean latency to the first fluid delivery (middle panel), and mean proportion of the total daily number of pellet deliveries prior to the first fluid delivery (bottom panel) as a function of pellet cost and available fluid for the 6 baboons that had restricted access to pellets.

able water from the spout at the back of the cage.

Discussion

The main purpose of this study was to determine how increasing the cost of food pellets affected pellet intake and intake of a fluid available at a constant cost. Increasing the response requirement for pellets decreased pellet intake and had minimal effects on vehicle intake. The secondary purpose of this study was to determine how changing the fluid altered the effects of increasing the cost of pellets. Increasing the response requirement for pellets decreased pellet intake to a greater extent when cocaine, compared to the vehicle, was available. Furthermore, increasing the cost for pellets also significantly increased cocaine intake to a greater extent than vehicle intake. The greater increase in cocaine intake than vehicle intake when the cost of pellets was increased indicates that self-administered cocaine functioned as an economic substitute for pellets in 6 of 8 baboons, an effect that was statistically significant for the group of 6 baboons whose access to pellets was restricted to 60% to 70% of nonrestricted intake.

Although the effects of cocaine were statistically significant, the magnitude of the effect was moderate, varied among baboons, and was not dose dependent. Moreover, this behavioral effect of cocaine was only evident at maximum pellet cost. In fact, at 0.40 of maximum pellet cost, the number of pellet deliveries was significantly greater when cocaine was available compared to vehicle. It is unclear why effects in opposite directions were observed at the 0.40 and maximum pellet cost: Duration of responding on the pellet lever, latency to the first fluid delivery, proportion of food pellets delivered prior to the first fluid delivery, and response rate did not differ between these two pellet costs.

It is possible that the more rapid decrease in pellet intake with increasing pellet cost when cocaine was available is accounted for by the anorectic effects of cocaine in baboons (Foltin, Fischman, & Nautiyal, 1990). Oral cocaine differs from other longer acting anorectic drugs in that it produces a pause in food intake, but when laboratory animals begin eating again they overeat, apparently to compensate for the pause, such that total daily caloric intake can be increased by cocaine. This anorectic effect may account for some of the variability in pellet intake. Anorectic efficacy, however, would not be sufficient to account for the greater increase in fluid intake when cocaine was available, compared to vehicle. If decreased pellet intake in the present study was due to the anorectic effects of cocaine taken throughout the day, then pellet intake should be similarly decreased when cocaine doses, similar to what would have been ingested, are given by the experimenter.

EXPERIMENT 2

Experiment 2 compared the effects of self-administered cocaine to experimenter-given cocaine. If self-administered cocaine decreased pellet intake to a greater extent than experimenter-given cocaine, then the greater decrease in pellet intake when cocaine was self-administered could not be accounted for entirely by cocaine's anorectic effects.

The greater decrease in pellet intake when cocaine was available may also have been an artifact of the ascending order in which pellet cost was examined. It is possible that prolonged food restriction increased the sensitivity of baboons to the anorectic effects of cocaine. Examination of the pellet-delivery curves in Figures 1 and 2 shows that the number of deliveries sometimes decreased with increasing pellet cost at the middle range of costs (FR 32 to 64), and then did not decrease at the next set of costs (FR 64 to 128), but decreased again at maximum cost. These plateaus may have been related to the order of testing the FR values. The finding that cocaine deliveries differed consistently only at maximum pellet cost may also be related to the order of testing the FR values. In Experiment 2, the effects of cocaine availability on responding maintained by food pellets was examined at five pellet costs.

In summary, Experiment 2 was designed to extend the findings of Experiment 1 with several experimental modifications, including (a) testing all baboons with nonrestricted access to food pellets, (b) providing experimenter-given cocaine in doses paired to the amount of cocaine that was self-administered, (c) systematically varying the order of testing FR values for food within and between baboons, and (d) increasing the length of exposure to each FR value for food.

Table 2

Order in which cocaine solutions (mg/kg/delivery) and its vehicle (a dextrose solution) were studied in each baboon in Experiment 2.

Baboon	Condition 1	2	3	4
2	Vehicle	0.008	0.016	0.032
3	Vehicle	0.032	0.016	0.008
4	Vehicle	0.008	0.016	0.032
5	Vehicle	0.032	0.016	0.008
6	Vehicle	0.016	0.032	0.008
7	Vehicle	0.016	0.008	0.032

Note. At the beginning of each fluid condition, responding for both fluid and food pellets was maintained under FR 2 schedules for 5 to 10 days to allow intake to stabilize. Once responding was stable, the FR value for pellet delivery was manipulated as shown in Table 3.

Table 3

Order in which FR values for food pellet delivery were studied in each baboon in Experiment 2 during each fluid condition shown in Table 2. Each FR value was in effect for 8 days.

Baboon	Condition 1	2	3	4	5
2	32	128	2	64	160
3	32	128	2	160	64
4	128	32	2	64	160
5	128	32	2	160	64
6	16	48	2	32	64
7	8	32	2	48	16

Method

Procedure. The 6 smaller baboons that had participated in the first experiment completed Experiment 2. Baboons weighed 21.4 to 30.8 kg at the start of this experiment. Weights remained relatively stable over the 5-month experiment, with final weights ranging from 18.5 to 31.4 kg. The housing conditions, equipment, and reinforcement schedule were as described above. Each of five response costs for pellets was examined when baboons had access to each of four fluids: (a) a dilute dextrose vehicle solution, (b) 0.008 mg/kg per delivery cocaine, (c) 0.016 mg/kg per delivery cocaine, and (d) 0.032 mg/kg per delivery cocaine. The order in which each fluid was studied for each baboon is shown in Table 2. Assuming no data were lost due to mechanical or human error, after responding for a fluid stabilized (no upward or downward trend for 3 consecutive days) each fluid condition was studied for 40 days (8 days at each of five response costs).

In order to provide a range of functionally equivalent pellet intakes in these 6 baboons, it was necessary to test different FR values in some baboons. Pellet costs (Table 3) were chosen, based on the data obtained in Experiment 1, such that pellet intake would be maintained at about 90%, 75%, 50%, and 25% of 23-hr intake under the FR 2 condition. In this experiment there were no restrictions, other than that imposed by the FR value, on total daily pellet intake. As shown in Table 3, the order of testing each cost was systematically varied such that the FR 2 was always tested in the middle of each set of manipulations. In order to prevent long periods of limited food intake, each cost was examined for 8 consecutive days.

During the first four sessions at each response cost, the baboons had concurrent access to a test fluid under an FR 2 schedule of reinforcement. Neither cocaine nor vehicle was available for self-administration during the last four sessions at each response cost. During two of these latter sessions, only pellets were available, while during the other two sessions, baboons were given fluids by the research technician at three times during the session: 12:00 p.m., 3:00 p.m., and 8:00 a.m. the following morning. The caloric and cocaine content of the experimenter-given deliveries were yoked to each baboon's own intake during the second, third, and fourth sessions when fluid was self-administered. The dose at noon hours was based on fluid consumption between 10:00 a.m. and 2:00 p.m., the dose at 3:00 p.m. was based on fluid consumption between 2:00 p.m. and 6:00 p.m., and the dose at 8:00 a.m. was based on fluid consumption between 6:00 p.m. and 9:00 a.m. the following morning, averaged across the 3 days. The solution consisted of Kool-Aid® flavored water to which (a) dextrose was added to match the caloric content of the self-administered fluid, and (b) cocaine was added to match the cocaine content of the self-administered fluid. The volume of experimenter-given fluid varied between 10 and 100 ml, depending on each baboon's drug intake. Fluid was given to each baboon by presenting a fluid spout at the front of the cage and allowing each baboon to drink at his own rate. Given the sweetness of the fluid, the baboons, with a few exceptions, drank the fluid rapidly. On the rare occasions that a baboon did not drink the fluid, that session's data were excluded from analyses. Although it was always necessary to complete the self-administration sessions prior to the no-alternative fluid and experimenter-given sessions, the order of the no-alternative fluid and experimenter-given sessions was systematically varied within and among baboons, such that at each FR value half of the baboons experienced the no-alternative fluid before the experimenter-given sessions and half experienced the experimenter-given before the no-alternative fluid sessions.

Data analysis. Data collected on the 2nd day of each no-alternative and experimenter-given condition and the 4th day of each self-administration condition under each cost were included in the analyses. Total daily pellet and fluid intake and latencies to the first food delivery and the first fluid delivery were analyzed using repeated measures analyses of variance with three categorical within-subject factors. The first factor was available fluid (no-alternative, in analyses of food intake only; dextrose; low, medium, and high cocaine dose), the second factor was experimental condition (no alternative, self-administered fluid, and experimenter-given fluid), and the third factor was pellet cost (five response costs). For each fluid condition, a planned comparison was also accomplished, comparing results obtained under the self-administration condition to results obtained under the no-alternative and experimenter-given conditions at maximum pellet cost. Results were considered statistically significant at $p < .05$.

Results

Figures 5 and 6 compare total daily pellet and fluid intake as a function of pellet cost, available fluid, and experimental condition for each baboon. The five response costs engendered a mean intake of 100%, 86%, 67%, 46%, and 30% of baseline pellet intake when no fluid was available. Pellet intake under each cost, when no fluid was available, was determined four times: Intake under each cost varied by less than 12% (minimum cost: ±5%; second cost: ±12%; third cost: ±4%; fourth cost: ±9%; fifth cost: ±10%). For example, pellet intake during the four times when pellets were available under the FR 2 condition ranged between 437 and 458 for Baboon 2.

Increasing pellet cost decreased pellet intake in all 6 baboons. Each of 6 baboons was tested with five FRs, such that under each fluid condition there were 30 tests comparing pellet intake when a fluid was self-administered to when the fluid was given by the experimenter. Pellet intake was lower on eight tests when vehicle was self-administered compared to when vehicle was given by the experimenter: one pellet cost for Baboons 2, 3, 4, and 5, and two pellet costs for Baboons 6 and 7 (e.g., FR 16, FR 32 for Baboon 7). Pellet intake was lower on 15 tests when the low cocaine dose was self-administered compared to when it was given by the experimenter: one pellet cost for Baboon 7; two pellet costs for Baboons 2, 3, and 6; three pellet costs for Baboon 5; and five pellet costs for Baboon 4. Pellet intake was lower on 12 tests when the medium cocaine dose was self-administered compared to when it was given by the experimenter: one pellet cost for Baboon 4; two pellet costs for Baboon 2; and three pellet costs for Baboons 3, 5, and 6. Pellet intake was lower on 19 tests when the high cocaine dose was self-administered compared to when it was given by the experimenter: two pellet costs for Baboons 2 and 4; three pellet costs for Baboon 7; and four pellet costs for Baboons 3, 5, and 6. For every baboon, there were more pellet costs when one or more doses of self-administered cocaine decreased pellet intake to a greater extent than experimenter-given cocaine compared to when vehicle was available.

Figure 7 presents mean total daily number of pellet deliveries as a function of pellet cost and experimental condition when baboons had access to pellets and concurrent access to the four fluids. Pellet intake varied significantly as a function of pellet cost, $F(4, 20) = 39.33$, $p < .0001$. The number of pellet deliveries at maximum cost was significantly lower when baboons self-administered the medium or high cocaine dose compared to when the same doses were experimenter given: medium dose: $F(1, 120) = 6.11$, $p < .0148$; high dose: $F(1, 120) = 8.33$, $p < .0046$. At every cost greater than FR 4, mean pellet intake when cocaine was self-administered was lower

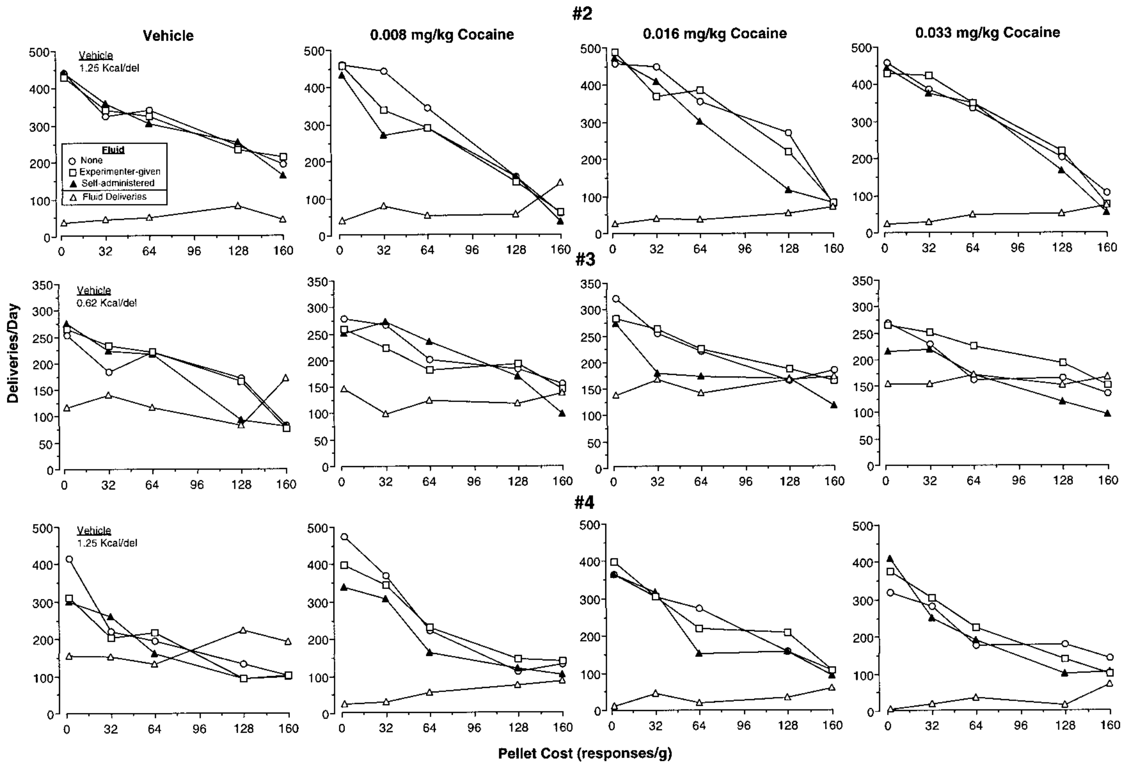

Fig. 5. Total daily number of pellet and fluid deliveries as a function of pellet cost, available fluid, and experimental condition for Baboons 2, 3, and 4, which had nonrestricted access to pellets. The closed triangles indicate the pellet deliveries on the 4th day of the condition in which cocaine or its vehicle was available for self-administration, and the open triangles indicate fluid deliveries on the same day. The circles indicate pellet deliveries on the 2nd day of the condition in which there was no alternative to pellets; the squares indicate pellet intake on the 2nd day of the condition in which there was no alternative to pellets, but the experimenter administered the fluid previously available during the 23-hr session.

than pellet intake when cocaine was given by the experimenter.

Increasing the cost of pellets increased vehicle intake by Baboons 3, 4, and 7, low-dose cocaine intake by Baboons 2 and 4, medium-dose cocaine intake by Baboons 2, 3, 4, and 6, and high-dose cocaine intake by Baboons 2, 4, 5, and 6. The top panel of Figure 8 presents mean total number of fluid deliveries as a function of pellet cost and available fluid. The number of cocaine deliveries did not differ from vehicle when pellets were available at minimum cost. Fluid intake varied significantly as a function of pellet cost, $F(4, 20) = 13.27$, $p < .0001$. When expressed as percentage change from the number of fluid deliveries earned when pellets were available at minimum cost, dextrose deliveries increased by 26%, low-dose cocaine deliveries increased by 51%, medium-dose cocaine deliveries increased by 60%, and high-dose cocaine deliveries increased by 80% from when pellets were available at minimum cost.

The bottom panel of Figure 8 summarizes the data from the top panel using a change measure derived by subtracting the number of fluid deliveries at minimum pellet cost from the number of fluid deliveries at each pellet cost. This graph makes it easier to see the small dose-dependent increases in cocaine self-administration as a function of increasing pellet cost.

The latency to the first fluid delivery varied between 25 and 170 min, and did not vary as a function of either pellet cost or fluid condition (data not shown). This is in contrast to the decrease in the latency to the first fluid delivery with increasing pellet cost observed in the baboons with restricted access to pellets in Experiment 1. As observed in the 2

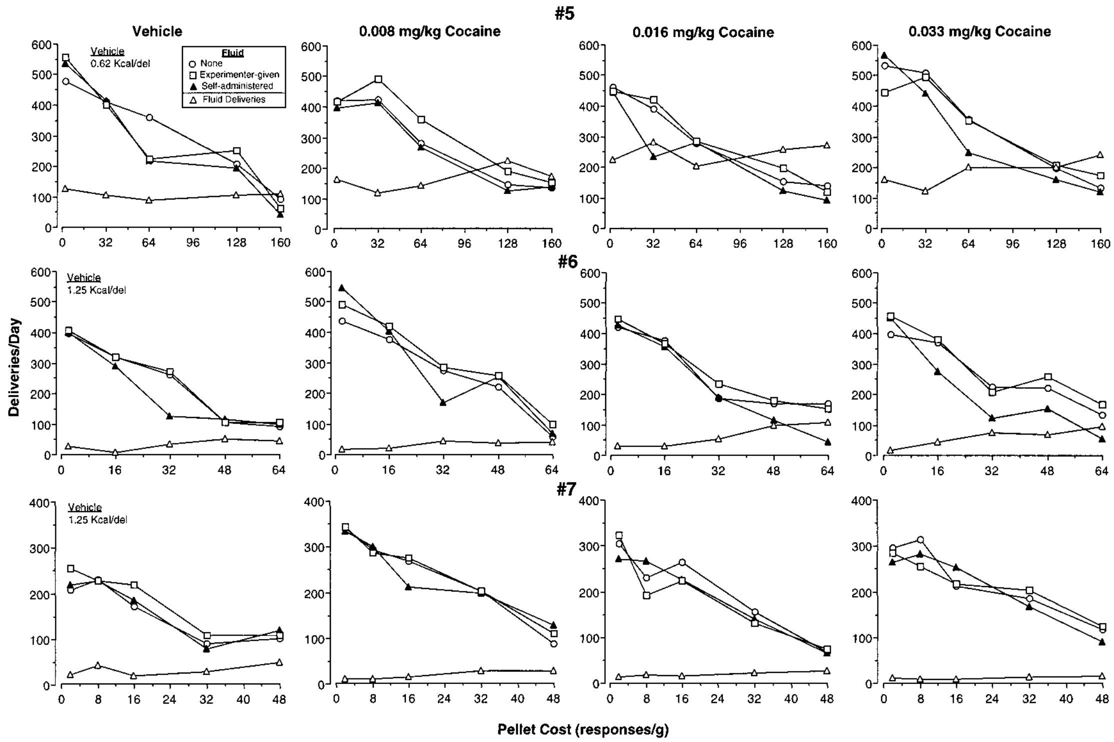

Fig. 6. Total daily number of pellet and fluid deliveries as a function of pellet cost, available fluid, and experimental condition for Baboons 5, 6, and 7, which had nonrestricted access to pellets. See Figure 5 for details.

baboons that had nonrestricted access to pellets in Experiment 1, the baboons in Experiment 2 received between 15% and 35% of their total daily pellet deliveries prior to responding for fluid when pellets were available at minimum cost. The proportion of pellets delivered prior to the first fluid delivery did not vary as a function of pellet cost or fluid condition (data not shown).

Discussion

Increasing the response requirement for pellets decreased the number of pellet deliveries. When baboons had access to a fluid solution, increasing the response requirement for pellets decreased the number of pellet deliveries to a greater extent than when no fluid was available. Statistical analyses indicated that the greater decrease in pellet intake when fluid was available was significant only when the medium and high cocaine doses were available. When expressed as a percentage of fluid intake when food pellets were available under an FR 2 schedule, increasing the response requirement for food increased the number of fluid deliveries to a greater extent when cocaine was available compared to vehicle. Self-administered oral cocaine thus functioned as an economic substitute for food pellets in baboons with nonrestricted access to food. The increases in cocaine intake, which ranged from 50% to 80%, although modest and not dose dependent, were larger than the increases in fluid intake observed when some of these same baboons had access to *d*-amphetamine (Foltin, 1997) or ethanol solutions (Foltin, 1998).

GENERAL DISCUSSION

Substitution (an increase in intake of one commodity when the cost of a second commodity is increased) among nonidentical commodities has been difficult to observe. Bickel et al. (1995) summarized eight drug studies, using both nonhuman and human participants. Only four of these studies used concurrently available nonidentical commodities. Moreover, the evidence for substitution was limited to a portion of the participants

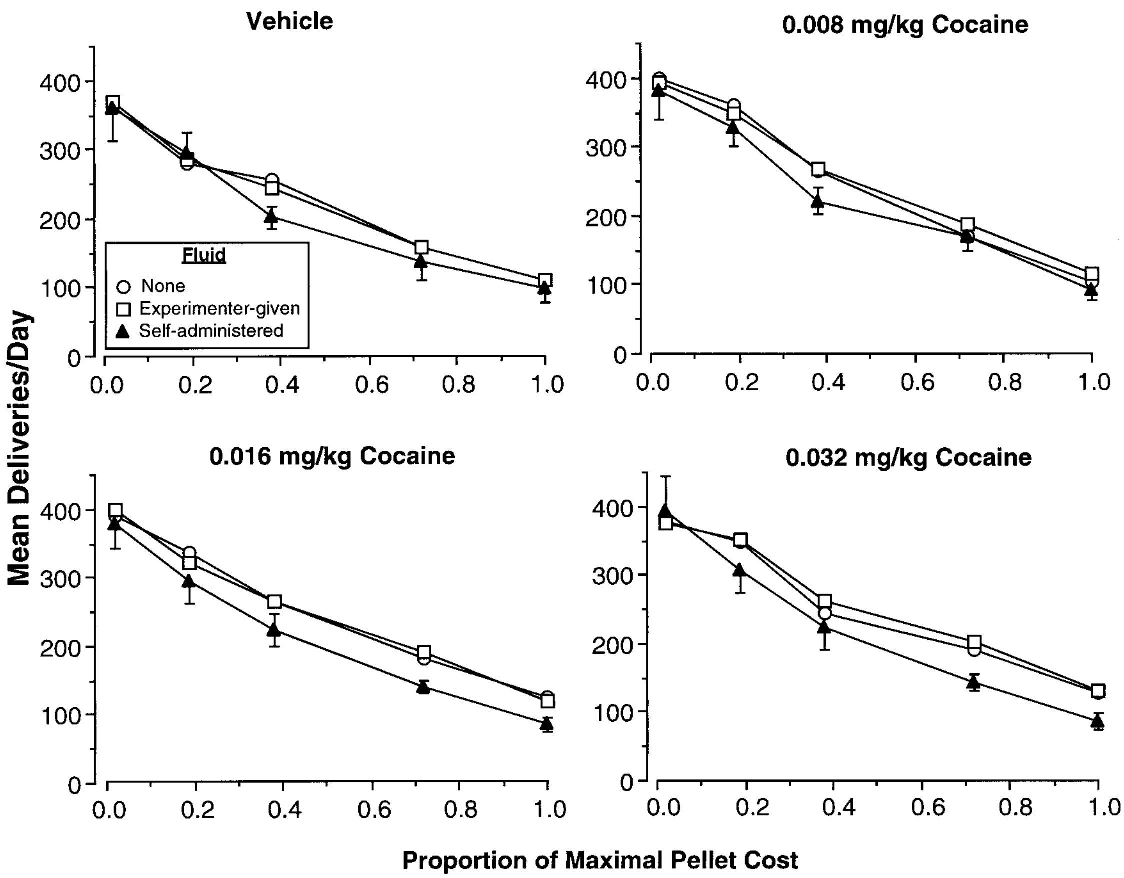

Fig. 7. Mean total daily number of pellet deliveries as a function of pellet cost and experimental condition when each of the four alternative fluids was available for the 6 baboons for which data are shown in Figures 5 and 6. Because the FR values that similarly reduced pellet intake varied among baboons, cost is expressed as a proportion of the maximum cost tested for each baboon. Error bars, representing ±1 *SEM,* are presented for the self-administration conditions only.

(Carroll, 1987; Carroll & Meisch, 1979; Samson, Tolliver, & Roehrs, 1983) or varied across studies from the same laboratory (Samson, Roehrs, & Tolliver, 1982; Samson et al., 1983). Although not included in the Bickel et al. (1995) review, Comer, Hunt, and Carroll (1994) reported that self-administered saccharin functioned as an economic substitute for smoked cocaine in rhesus monkeys. Petry and Heyman (1995) reported that increasing the cost of a 10% sucrose solution dramatically increased consumption of a 10% sucrose plus ethanol solution. Although the two commodities were both sucrose based, their study demonstrated substitution for nonidentical commodities. The present data confirm that substitution between drug and food can be observed, but the effect is not that robust or large.

It is important to note that an increase in consumption of an alternative would not be possible if there were restrictions on "income" (e.g., short session length, a maximum number of responses permitted per session, etc.). The small increases in consumption of a nonsubsistence commodity in the present study were possible because there were no restrictions on income beyond that imposed by session length. Although baboons responded up to 20,000 times a session for pellets, this accounted for only about 2 hr of each 23-hr session. Adding 2 hr to this total to account for the timeout between reinforcers, and assuming 8 hr for sleep, still leaves 9 hr of "leisure"

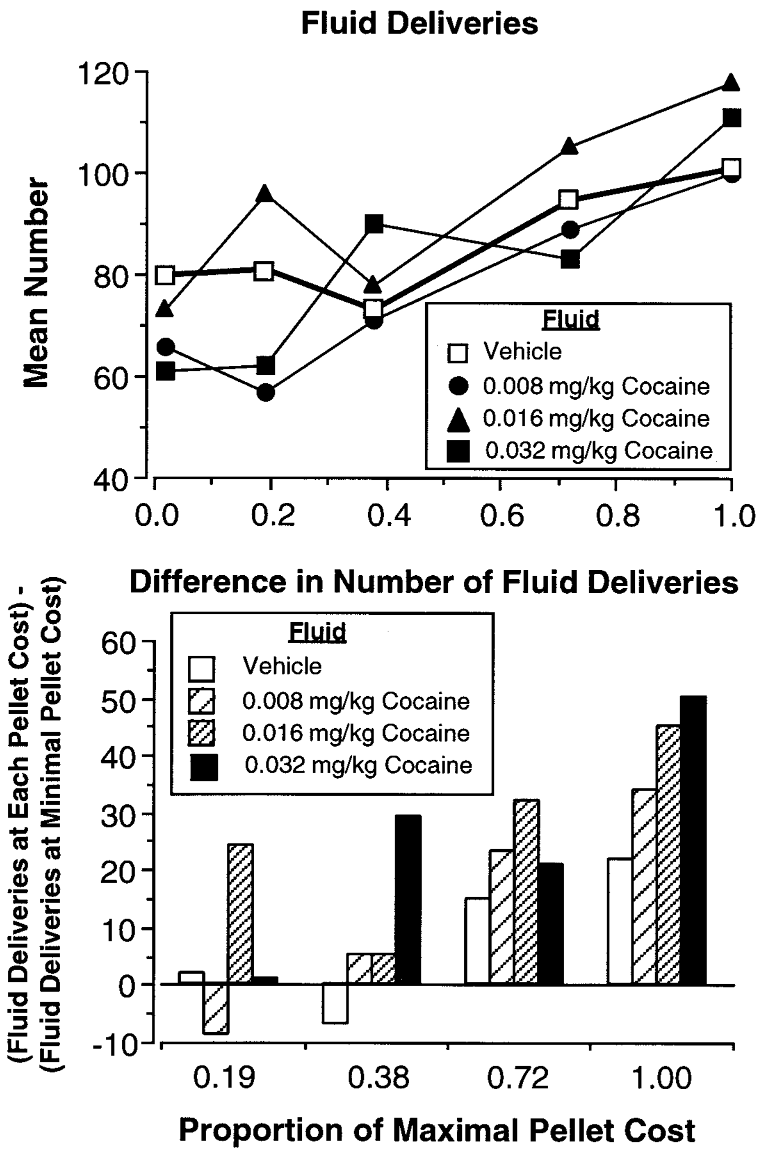

Fig. 8. Top panel: mean total daily number of fluid deliveries as a function of pellet cost and available fluid for the 6 baboons for which data are shown in Figures 5 and 6. Note that the *y* axis does not begin at zero. Bottom panel: change in the mean number of fluid deliveries at each pellet cost compared to fluid intake when pellets were available at minimum cost for each of the four available fluids.

time. Given this available time, and the fact that fluid was delivered following only two responses, there was plenty of session time (income) for responding maintained by fluid.

The importance of income in choice behavior between two commodities has been demonstrated in numerous studies using laboratory animals (e.g., Shurtleff, Warren-Boulton, & Silberberg, 1987). Decreasing income has been reported to shift choice between food pellets and saccharin to pellets (Shurtleff et al., 1987); between heroin and food pellets, in animals not physically dependent on heroin, to food (Elsmore, Fletcher, Conrad, & Sodetz, 1980); and between phencyclidine and saccharin to phencyclidine (Carroll & Rodefer, 1993). In the present case, it would be predicted that increasing the cost per cocaine delivery, which would be functionally equivalent to decreasing income, would limit the increase in cocaine intake when the cost of pellets was increased.

Food deprivation, resulting in decreased body weight, increases the oral and intravenous self-administration of a range of drugs (Carroll & Stotz, 1983, 1984; Carroll, Stotz, Kliner, & Meisch, 1984; Meisch & Thompson, 1973). It is unclear if this effect of body-weight reduction is related to economic substitution for food by drug, or is an independent phenomenon. When rats orally self-administering etonitazene were first food deprived, oral drug intake increased slowly over 17 days, but when deprivation was imposed a second time, oral drug intake increased within several days (Carroll & Meisch, 1979). These results suggest that experience with deprivation may play a role in food-deprivation-induced increases in oral drug self-administration. In the present paradigm, increasing pellet cost increased cocaine intake within a single session, but all baboons had extensive experience with the current schedule conditions. An important difference between work completed with rats and the current study is that rats rapidly lose weight when food is restricted, whereas baboons do not. Although increases in drug intake caused by body-weight loss and increases in drug intake caused by increasing the cost for food, without changes in body weight (i.e., substitution), are related phenomena, further research is necessary to elucidate the boundary conditions under which substitution for food by self-administered drugs can occur.

There are at least three limitations imposed by the current methodology that may affect the generality of the findings: (a) These observations were based on 23-hr daily sessions, which have been rarely used in other studies; (b) the data were collected in unusually large laboratory animals (three to six times the weight of a rhesus monkey; 100 times the weight of a rat); and (c) each FR value, or condition within FR value (i.e., self-administered vs. experimenter-given fluid in Experiment 2), was examined for a predetermined 2 or 4 days, rather than using a stability criterion to determine how long each condition was tested. In spite of these limitations, the decreases in responding for a commodity with increasing cost were reliable and demonstrable with only 2-day conditions. The brief testing of each FR value or condition may have increased the variability, thus decreasing power. The design was selected because it provided parametric data in the same animals over a reasonable time frame.

The present data also provide an interesting observation on the effects of cocaine on responding maintained by food pellets. The decrease in pellet intake when the cost of pellets was increased was greater when cocaine, compared to vehicle, was also available. In behavioral economic terms, demand for pellets was more elastic when cocaine was available (i.e., maximum responding for pellets occurred at a lower cost when cocaine was available). A similar effect was observed when baboons had restricted access to pellets and a high-dose amphetamine solution was available (Foltin, 1997), but not when an ethanol solution was available (Foltin, 1998).

The effect of having an alternative source of calories on responding maintained by food pellets in baboons was examined in an earlier study (Foltin, 1992). Pellet intake decreased at the slowest rate when there was no alternative caloric source, at an intermediate rate when a calorically matched fluid was the alternative, and at the highest rate when identical pellets were the alternative. Caloric alternatives increased the elasticity of demand for pellets. Bauman, Raslear, Hursh, Shurtleff, and Simmons (1996) reported that, in rhesus monkeys, responding maintained by food pellets was unaffected by the availability of a sweet nonnutritive fluid, regardless of pellet cost.

The greater decrease in pellet intake when cocaine was available may also be related to the fact that cocaine is an effective anorectic drug (Foltin et al., 1990). For this reason, in Experiment 2 cocaine was administered in experimenter-given doses, yoked to the amount of cocaine self-administered by each baboon. If the greater decrease in pellet intake was due to the anorectic effects of cocaine or the caloric content of the vehicle, pellet intake should have been similarly decreased by experimenter-given cocaine. This was not the case (i.e., experimenter-given cocaine failed to decrease pellet intake). Thus, the effect of self-administered cocaine on pellet intake was not purely a function of the anorectic effects of cocaine or the caloric content of the vehicle. Of course, it is still possible that if experimenter-given doses were given more often throughout the day, then pellet intake would have decreased. Thus, the results of the experimenter-given dosing are only suggestive, not definitive.

Although there were procedural differences between Experiments 1 and 2, comparisons of the studies provide some suggestive information about the effects of restricted access to food under the current experimental conditions. First, it was expected that food restriction would increase cocaine self-administration when pellets were available under the FR 2 schedule. This was not the case: Cocaine intake was similar when baboons had restricted access to pellets and when they had nonrestricted access to pellets. Second, it was expected that food restriction would increase the substitution by cocaine for pellets. This was the case: Increasing pellet cost significantly increased cocaine intake only when access to pellets was restricted. Third, it was expected that food restriction would decrease the effect of self-administered cocaine on responding maintained by pellets. This was the case: Self-administered cocaine produced larger shifts to the left in the pellet-intake function (demand curve) when there were no restrictions, other than those imposed by the FR schedule, on responding maintained by pellets.

In summary, increasing the response requirement for pellet delivery decreased pellet intake and increased fluid intake to a greater extent when a dose of oral cocaine, rather than its vehicle, was concurrently available. This indicated that self-administered cocaine functioned as an economic substitute for pellets. Furthermore, the effects of cocaine on responding maintained by food were modulated by environmental restrictions on total daily pellet intake. The mechanism by which self-administered cocaine has this effect on food intake remains unclear.

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APPENDIX

Total duration of responding on food pellet lever, latency to the first fluid delivery, and proportion of pellets delivered before the first fluid delivery for the 1st day of each fluid condition for individual baboons with restricted access to food in Experiment 1. Group mean data are presented in Figure 4.

			Cocaine dose (mg/kg)		
Pellet FR	No fluid	Dextrose	0.008	0.016	0.032
Duration (min) of responding on food pellet lever					
Baboon 1 (restricted to 60% of baseline pellet intake)					
2	3.9	3.6	3.4	3.4	
16	48.5	47.8	56.8	43.3	
32	101.9	88.0	98.2	89.7	
64	144.1	196.5	171.3	163.2	
128	207.4	166.8	160.1	184.6	
160	137.1	158.9	150.2	135.4	
Baboon 8 (restricted to 60% of baseline pellet intake)					
2	3.4	1.6	1.3	1.3	1.5
16	14.3	19.0	21.4	18.3	18.3
32	23.7	38.2	40.6	40.0	41.1
48	42.1	33.0	65.2	80.7	71.9
64	54.1	26.6	36.9	42.4	41.5
Baboon 3 (restricted to 70% of baseline pellet intake)					
2	1.4	0.6	0.8	0.7	0.6
16	11.4	12.1	13.5	13.3	15.4
32	26.5	25.6	30.0	34.9	28.3
64	53.2	51.8	64.3	76.8	52.9
128	117.1	109.1	77.3	112.3	90.9
160	154.6	107.2	63.3	43.9	94.3
Baboon 4 (restricted to 70% of baseline pellet intake)					
2	1.4	2.2	3.0	1.3	2.6
16	44.3	43.8	30.5	23.8	27.5
32	82.6	86.7	42.5	65.5	41.1
64	147.1	165.7	66.3	120.5	73.9
128	168.8	132.5	75.0	115.5	81.5
160	186.7	144.5	91.2	128.2	90.8
Baboon 5 (restricted to 70% of baseline pellet intake)					
2	2.4	4.6	2.6	2.7	3.1
16	100.8	51.7	44.6	43.6	44.0
32	201.1	106.2	95.7	87.5	90.9
64	398.9	204.2	209.8	213.3	201.0
128	378.8	335.3	356.2	342.5	317.7
160	26.6	232.3	227.9	294.0	323.8
Baboon 7 (restricted to 70% of baseline pellet intake)					
2	1.0	0.9	0.8	0.8	0.9
8	14.4	14.6	15.6	14.6	11.4
16	29.0	30.6	29.7	27.4	27.8
32	36.2	33.0	45.6	20.0	48.8
48	16.6	29.1	22.3	14.5	16.7

APPENDIX

(*Continued*)

Pellet FR	No fluid	Dextrose	Cocaine dose (mg/kg) 0.008	0.016	0.032
Latency (min) to the first fluid delivery					
Baboon 1 (restricted to 60% of baseline pellet intake)					
2		344	161	171	
16		141	137	138	
32		43	205	19	
64		2	20	1	
128		33	11	2	
160		3	2	8	
Baboon 8 (restricted to 60% of baseline pellet intake)					
2		8	148	112	141
16		49	216	179	142
32		151	137	317	167
48		126	31	163	149
64		2	83	2	36
Baboon 3 (restricted to 70% of baseline pellet intake)					
2		58	101	111	101
16		104	117	47	141
32		85	84	155	142
64		65	29	69	162
128		21	10	15	11
160		7	3	4	3
Baboon 4 (restricted to 70% of baseline pellet intake)					
2		211	253	266	243
16		186	15	278	174
32		249	80	1	133
64		323	74	61	12
128		109	5	58	74
160		89	28	56	137
Baboon 5 (restricted to 70% of baseline pellet intake)					
2		222	291	245	335
16		276	267	298	274
32		363	134	307	321
64		448	7	3	155
128		7	4	2	0
160		0	0	3	3
Baboon 7 (restricted to 70% of baseline pellet intake)					
2		146	134	94	97
8		153	64	104	95
16		150	48	98	157
32		15	54	2	18
48		57	35	53	54

APPENDIX

(*Continued*)

Pellet FR	No fluid	Dextrose	Cocaine dose (mg/kg) 0.008	0.016	0.032
Proportion of pellets delivered prior to first fluid delivery					
Baboon 1 (restricted to 60% of baseline pellet intake)					
2		.07	1.00	.89	
16		.18	1.00	.54	
32		.35	.70	1.00	
64		.12	.03	.46	
128		.09	.06	.26	
160		.02	.11	.02	
Baboon 8 (restricted to 60% of baseline pellet intake)					
2		.55	1.00	1.00	1.00
16		.83	1.00	.38	1.00
32		.62	.65	1.00	1.00
48		.88	.15	.36	.98
64		.88	.07	.01	.05
Baboon 3 (restricted to 70% of baseline pellet intake)					
2		1.00	.78	.80	.80
16		.57	.53	.56	.56
32		.15	.61	.07	.07
64		.01	.05	.00	.00
128		.00	.02	.01	.01
160		.01	.02	.01	.01
Baboon 4 (restricted to 70% of baseline pellet intake)					
2		1.00	1.00	1.00	1.00
16		.90	.51	.89	.69
32		.31	.11	.47	.86
64		.10	.01	.04	.04
128		.08	.02	.13	.05
160		.10	.03	.16	.06
Baboon 5 (restricted to 70% of baseline pellet intake)					
2		1.00	1.00	1.00	1.00
16		1.00	1.00	1.00	1.00
32		1.00	.44	1.00	1.00
64		1.00	.01	.00	.36
128		.01	.01	.00	.00
160		.00	.00	.01	.01
Baboon 7 (restricted to 70% of baseline pellet intake)					
2		1.00	.92	1.00	.98
8		.80	.06	1.00	.62
16		.57	.23	.01	.35
32		.46	.17	.20	.02
48		.28	.01	.17	.17